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DUANE ARNOLD ENERGY CENTER
CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY

ANNUAL REPORT

January, 1987 - December, 1987

Submitted by

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 14th year of station operation (January, 1987 to December, 1987).

The Duane Arnold Energy Center Operational Study was implemented in mid January, 1974. Prior to plant start-up, extensive pre-operational data were collected from April, 1971 to January, 1974. These pre-operational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of 14 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the Iowa Electric Light and Power Company, is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers, which require a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These pre-operational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water, and were first implemented in January, 1974.[4-16]

The specific objectives of the operational study are twofold:

1. to continue routine water quality determination in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.

2. To conduct physical, chemical, and biological studies in and adjacent to the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities adjacent to the discharge.

STUDY PLAN

During the operational phase of the study, sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): (1) Upstream of the plant at the Lewis Access Bridge (Station 1), (2) directly upstream of the plant intake (Station 2), (3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3), and (4) adjacent to Comp Farm, about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering, University of Iowa. From January, 1979 through December, 1983 samples were collected and analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analysis.

Samples for routine chemical, physical, and biological analysis were taken twice per month while other studies were conducted seasonally. The following are discussed in this report:

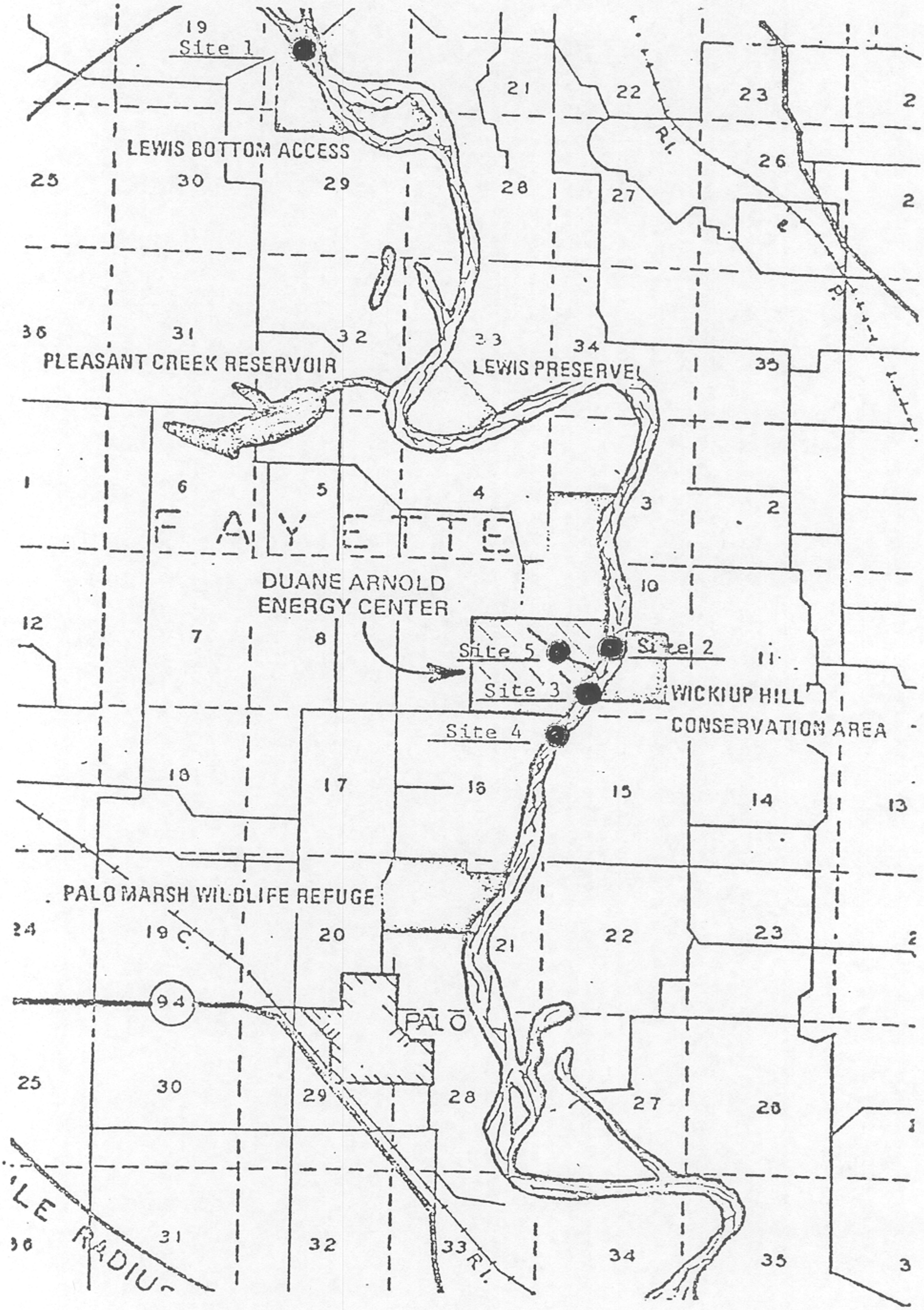

Figure 1. Location of Operational Sampling Sites

I. General Water Quality Analysis

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved and suspended)
4. Dissolved oxygen
5. Carbon dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical oxygen demand
14. Coliform series (total and fecal)

II. Additional Chemical Determinations

A. Frequency: twice yearly

B. Location: at all five stations

C. Parameters measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic studies

1. Frequency: summer and fall
2. Location: at all five stations

B. Asiatic Clam (*Corbicula*) survey

1. Frequency: twice yearly
2. Location: upstream and downstream of the plant intake bay, and cooling tower basin.

C. Impingement studies
1. Frequency: daily
2. Location: intake structure

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

Mean monthly flows in the Cedar River during the period January-December, 1987 were generally lower than those present in 1986, ranging from 224% of the median monthly discharge in February to 50% in June. Estimated mean flow for the year was ca. 2,625 cfs, the third lowest mean flow observed during the 1972-1987 period, and substantially below the 15 year average flow of ca. 5,040 cfs. Mean monthly discharges at the Cedar Rapids gauging station ranged from 1,418 cfs in October to 5,109 cfs in April. Mean monthly discharges in 1987 were classified as excessive (greater than the 75% quartile) in three months (January, February, and December) and deficient (less than the 25% quartile) in June. Winter flows varied from ca. 1,160 to 3,800 cfs until early March and then rose rapidly to a spring high of 6,670 cfs on March 31, 1987. Flows generally declined from mid April through mid May to ca. 2,500 cfs, and then increased slightly to ca. 3,700 cfs by the end of the month. Summer flows remained low through mid August, ranging from ca. 3,000 cfs in early June and mid July to 1,040 cfs on August 4. Flows increased sharply in late August, reaching a yearly maximum of 9,010 cfs on August 27. Discharge remained slightly above normal in September, ranging from 1,620 to 2,130 cfs, but declined to below normal levels of ca. 1,200 to 2,450 cfs in October and November. December flows were well above normal, ranging from ca. 1,100 to 3,100 cfs. Hydrological data are summarized in Table 1.

Temperature (Table 2)

Ambient river temperatures during the period ranged from 0.0°C (32.0°F) to 29.5°C (85.1°F). The maximum ambient temperature observed upstream of the plant (Station 1) on July 22 was somewhat higher than those of the past three years. The maximum downstream temperature of 29°C (84.2°F) was observed at both downstream locations (Stations 3 and 4) on the same date. The highest discharge canal (Station 5) temperature observed during the period, 30°C (86° F), was recorded on August 12. The Duane Arnold Energy Center was off-line from mid March through early July, 1987 and most temperature differentials between upstream and downstream river locations were minimal. A maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Station 2 vs. Station 5) of 18°C (32.4°F) was observed on December 22.

The maximum ΔT value between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal of 4°C (7.2°F), was also measured on December 9. The maximum temperature elevation at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) of 2° C (3.6°F) was observed on March 5. There was no instance in which a temperature elevation in excess of the Iowa water quality standard was observed. No other samples taken at Station 4 exhibited temperature differentials in excess of 1.5°C (2.7°F) above ambient. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

Turbidity (Table 4)

In spite of lower river flows, turbidity values were similar to those of the previous year. Peak values of 110 NTU occurred at all river locations during late August during a period of high river flow. In general, highest values occurred during periods of runoff while low values (3-7 NTU) occurred during the winter. Turbidity values in the discharge canal were occasionally higher than those observed in river samples. A maximum discharge canal turbidity of 260 NTU was also observed on August 27.

<u>Solids</u> (Tables 5-7)

Solids determinations included total, dissolved, and suspended. Total solids values in upstream river samples were similar to those observed in 1986 and continued to exhibit little variation during the year. Values ranged from 290 to 500 mg/L, with the majority falling between 350 and 450 mg/L.

Dissolved solids values were relatively low throughout the year. Upstream values ranged from 170 mg/L during an extended period of low river flow in June and July to 400 mg/L in Late January. Dissolved solids, values at Station 3, 140 feet downstream of the discharge canal, were somewhat higher than values observed upstream of the discharge canal. A maximum downstream value of 730 mg/L was observed at Station 3 on December 9. Dissolved solids values at Station 4, one-half mile below the plant, were generally similar to upstream levels, ranging from 160 mg/L in July to 460 mg/L in November.

Suspended solids values at all river locations were relatively low, ranging from 4 to 230 mg/L. Low values occurred in the winter, while high values occurred in August and September during periods of rainfall and high runoff.

Due to concentration in the blowdown, total and dissolved solids values in the discharge canal were consistently higher than in the river samples. Maximum total solids concentrations of 2,030 mg/L were observed in the discharge canal in December, while a minimum value of 260 mg/L was observed on July 8 when the station was not operating.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected during 1987 ranged from 7.6 to 16.8 mg/L (88 to 189 % saturation). Dissolved oxygen concentrations in excess of saturation were frequently observed in the river from June through early September. This is in contrast to the previous year when values were rarely in excess of saturation.

Dissolved oxygen concentrations in the discharge canal (Station 5) exhibited marked variation, ranging from 1.5 to 16.6 mg/L. The extremely low value occurred during a period of low discharge canal flow in February, and was probably associated with benthic oxygen demand. With this exception values usually occurred during periods of highest temperatures. The highest value (151% saturation) was observed in March and appeared to be associated with photosynthetic activity. Other high values occurred during the winter period when temperatures in the canal were relatively low.

Carbon Dioxide (Table 9)

Carbon dioxide concentrations ranged from <1 to 26 mg/L. Lowest values occurred from June through early August. The highest value was associated with runoff in August, but high levels also occurred during the winter.

Alkalinity, pH, Hardness (Tables 10-14)

These closely related parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Total alkalinity values in river samples ranged from 92 to 242 mg/L. Lowest values occurred from mid June through early August during an extended low flow period. High values occurred during the winter months.

Carbonate alkalinity was rarely present in river samples during the current year. Values ranged from <1 mg/L during most of the period to 36 mg/L in mid August.

Values for pH in river samples ranged from 7.1 to 9.3. As in previous years, high values usually coincided with periods of increased photosynthetic activity. pH values in the discharge canal ranged from 7.3 to 9.1

Total hardness values in the upstream river generally paralleled total alkalinity levels. The highest values (325-350 mg/L) generally occurred during the winter, while low values of ca. 140-175 mg/L occurred in June and July.

The low alkalinity and hardness levels which occurred during an extended dry period appear to be related to the rapid downward movement of surface water through the dry unconsolidated surficial deposits into the shallow aquifers feeding the Cedar River. This rapid movement of water shortens its residence time in the surface deposits and shallow aquifer, and reduces the time available for the solubilization of calciferous materials.

Hardness values in the discharge canal were consistently higher during periods of station operation than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 143 mg/L when the station was off-line in July to 1,270 mg/L in December. Levels downstream of the station were generally higher than upstream values during periods of station operation.

Calcium hardness levels were substantially lower than total hardness values but exhibited similar variations. Values ranged from 34 to 230 mg/L in river samples, and from 51 to 847 mg/L in the discharge canal.

Phosphates (Tables 15 and 16)

In general, total phosphate concentrations in upstream river samples were similar to those observed during 1986 (Table 28). Ambient concentrations in the river ranged from 0.05 mg/L in April to 0.49 mg/L in September. High phosphate levels frequently occurred during periods of rainfall and increasing runoff. Levels in the discharge canal were frequently higher than those observed in the river. A maximum value of 2.3 mg/L was observed in the discharge canal in August.

Orthophosphate concentrations in river samples ranged from <0.01 mg/L in May and August to a maximum value of 0.40 mg/L in August. As in previous years, orthophosphate concentrations were lower than total phosphate levels. As expected, the greatest differential between total and orthophosphate concentrations coincided with large plankton populations and the resultant uptake of orthophosphate.

Ammonia (Table 17)

Average ammonia nitrogen concentrations in the river remained low throughout 1987. Concentrations ranged from <0.01 to 0.16 mg/L. Highest concentrations occurred in February and March. Low values consistently occurred during the dry summer period.

Nitrate (Table 18)

Nitrate concentrations were slightly lower in 1987 than during 1986 (Table 28), likely due to the dry weather and low river flows present. During the current year, nitrate values in river samples ranged from ca. 1.0 mg/L (as N) in July to 13.0 mg/L (as N) in late May. The average nitrate nitrogen concentration at Station 1, located at Lewis Access upstream of the plant, was 5.6 mg/L, 1.2 mg/L lower than the 1986 average. Nitrate concentrations equal to or in excess of the 10 mg/L (as N) EPA drinking water standards[18] were observed in the river on only two occasions, in May and December. Concentrations of less than 3 mg/L (as N) were observed from mid June through mid August, when river flows were low. Nitrate concentrations were frequently higher in the discharge canal than in river samples, due to reconcentration in the blowdown. Maximum nitrate nitrogen concentrations of 24 mg/L were observed in the discharge canal in December.

Iron (Table 19)

Iron concentrations in the river were similar to those observed in 1986. Concentrations in river samples in 1987 ranged from 0.06 to 1.7 mg/L. Concentrations in excess of 1 mg/L occurred in March, August, and September in conjunction with increasing river flow.

Low values of 0.2 mg/L or less occurred during the winter. As in previous years, high iron concentrations were usually observed associated with high turbidity and suspended solids values, indicating that most of the iron present is in the suspended form rather than in solution. Iron levels continued to be higher in the discharge canal during periods of station operation than in river samples. A maximum iron value of 3.4 mg/L was observed in the canal in August.

Biological Conditions

Biochemical Oxygen Demand (Table 20)

Average five-day biochemical oxygen demand (BOD_5) values were higher than those observed in 1986. Levels in the river ranged from <1 to 16 mg/L. Because of minimal runoff relatively high values were not observed during the spring, and the winter and spring periods were characterized by low BOD levels of 4 mg/L or less. High BOD values, ranging from 8 to 16 mg/L, were consistently observed from May through mid August, when river flows were low and large algal populations were present.

Coliform Organisms (Tables 21 and 22)

Determination of total and fecal coliform bacterial populations were reinstituted in 1984 after being discontinued in 1978. In spite of low river flows, average coliform values were higher than those observed during 1986 and exhibited more variation than those of the previous year. Highest counts continued to occur during periods of increasing river flow. A maximum total coliform count of 75,000 organisms/100 ml was observed one-half mile below the plant (Station

4) on September 16. The maximum observed fecal coliform level, 23,000 organisms/100 ml, also occurred at the same time. Low total coliform counts of 60 to 200 organisms/100 ml were observed during periods of relatively low flow in January, June, and October. Minimum fecal coliform concentrations of less than 10 organisms/100 ml were observed in January and February.

There appeared to be little difference between coliform densities upstream and downstream of the station.

ADDITIONAL STUDIES

In addition to the routine monthly studies, a number of seasonal limnological and water quality investigations were conducted during 1987. The studies discussed here include additional chemical determinations, benthic and impingement studies, and an Asiatic clam (*Corbicula*) survey.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on March 19 and July 22. The March samples were analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury, and zinc, while the July samples were analyzed for heavy metals only. In general, concentrations fell within the expected ranges and were similar to those observed during the previous year.

Concentrations of most heavy metals in the 1987 samples were low throughout the year. With the exception of manganese and zinc, all values were below detection limits on both sampling dates, and no violations of water quality standards[17] were observed. Chloride and sulfate concentrations in the March samples were within the expected ranges. The results of the additional chemical determinations are given in Table 23.

Benthic Studies

Bottom samples were taken at two locations upstream and downstream of the station in April and October, 1987, by means of Ponar dredge. No organisms were found in either of the downstream samples and a total of only three organisms (one mayfly nymph and two beetle larvae) were found in the downstream samples. Although these numbers appear extremely low, they are compatible with earlier studies that indicated the shifting sand and silt bottom supports a benthic community of very limited size and diversity. No organisms were found in the 1986 Ponar dredge samples.

Three artificial substrates (Hester-Dendy) were placed at each of the four sampling locations upstream and downstream of the station and in the discharge canal in June and October. These substrates were collected in July and December following a six-week colonization period. Thirteen of the original 15 substrates were recovered from the Cedar River following colonization the the summer, and 14 of the 15 in the fall. As in previous years, substrate samples were characterized by far greater numbers and species diversity than the natural substrate (Ponar dredge) samples. A total of 27 taxa were identified during the two sampling periods; 24 in July and 21 in December. The July discharge canal samples were dominated by midge (chironomid) larvae, while midge and caddisfly (tricoptera) larvae were the most common organisms observed on the July river substrates. Midge larvae and stonefly (plectoptera) nymphs were the most common organisms on the December river substrates. The December discharge canal substrates contained few organisms, principally midge larvae and snails. In general, there was little difference in the size or composition of benthic populations between upstream and downstream locations.

As in previous years, the artificial substrate studies indicate the Cedar River, both upstream and downstream of the Duane Arnold Energy Center, is capable of supporting a relatively diverse macroinvertebrate fauna in those limited areas where suitable bottom habitat is available. The results of the benthic studies are given in Tables 24 and 25.

Asiatic Clam Survey

In past years several power generation facilities have experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (Corbicula sp.). Although this clam is common in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy Center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine Cedar River monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been collected on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1986 investigations.

The Corbicula surveys conducted during 1987 continued to be negative. Samples were taken on April 22 and October 8, 1987. During the April survey an inspection of sediment samples for the presence of Corbicula sp. was conducted at the intake structure, discharge canal, cooling tower basins, and in the river upstream and downstream of the station. No Corbicula was observed.

On October 8 Ponar dredge samples collected from the cooling towers, inside the intake structure, and in the river upstream and downstream of the station were inspected for the presence of Asiatic clams. No freshwater clams of any species were collected.

Impingement Studies

The total numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1987, as reported by Iowa Electric personnel,continued to be very low and were somewhat less than those observed in 1986. Daily counts conducted by DAEC station personnel indicated a total of 261 fish were impinged during 1987. Highest impingement rates continued to occur during the winter. During the months of January, February, and March, 240 fish were removed from the trash baskets. The month with the highest impingement rates was January, when 96 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 26.

DISCUSSION AND CONCLUSIONS

The results of the studies conducted on the Cedar River during 1987 continue to support the conclusion that operation of the Duane

Arnold Energy Center has a minimal impact on the limnology and water quality of the river. This was especially relevant during the current year, since the mean river flow of ca. 2,625 cfs was the lowest present since 1977, and substantially below the 16 year average flow of ca. 5,020 cfs. As a result, the effects of station discharge on the downstream river would be expected to be more significant. However, in spite of the low flow conditions, downstream impacts were minimal. Although station operation resulted in temperature increases in the discharge canal, ranging from <1 to 18°C (<1.8 to 32.4°F), downstream temperatures one-half mile below the plant were rarely more than 1°C (1.8°F) above ambient and never exceeded upstream temperatures by more than 2°C (3.6°F). Even within the mixing zone (Station 3), ΔT values never exceeded 4°C (7.2°F). At no time were observed temperature differentials in violation of water quality standards. Several other parameters, i.e., dissolved solids, hardness, phosphate, nitrate, and iron were usually present in higher concentrations in the discharge canal during periods of station operation than at upstream locations, due to reconcentration in the blowdown discharge. However, only dissolved solids and hardness values were substantially higher in the mixing zone (Station 3), and increases downstream of the mixing zone at Station 4 were minimal. Average values for the above mentioned parameters during periods of station operation are summarized in Table 27.

During the 1987 study no parameters were observed in the river samples at levels in excess of the applicable Iowa Water Quality Standards[17]. Nitrate concentrations in excess of 10 mg/L (as N) were observed on two occasions, once upstream and once in the mixing zone, but these high values are related to runoff from agricultural land rather than station operation. In addition, nitrate limitations are applicable only to Class "C" waters which are protected as a raw water source for a potable water supply. The Cedar River in the vicinity of the Duane Arnold Energy Center is designated as a Class "A" and "B" stream. Class A waters are protected for primary contact and include limits on fecal coliform content during the April-October period. However, the standards apply to coliform levels related to waste water discharges rather than surface runoff. A review of the 1987 fecal coliform data indicate that lowest coliform values occurred during low flow periods when surface runoff was at a minimum. During these low flow periods there was never any appreciable difference between upstream and downstream coliform values.

As in previous years, the operation of the Duane Arnold Energy Center appeared to have an insignificant impact on the fish or other aquatic organisms found in the Cedar River. Fish impingement rates continued to be minimal and were far below levels that would adversely effect the river fishery.

The benthic community of the Cedar River in the vicinity of the Duane Arnold Energy Center has been characterized by low diversity and productivity throughout the entire study period. This condition is not related either to station operation or poor water quality, however. The river bottom in the vicinity of the Duane Arnold Energy Center is characterized by a shifting sand and silt substrate, both above and below the plant, which is not conducive to the development of a diverse and productive benthic community. When artificial substrates (Hester-Dendy) are placed in the river they develop similar populations, both upstream and downstream of the station, which are characterized by relatively high species diversity and many organisms indicative of relatively good water quality. Thus, runoff from agricultural land and the resultant silt deposition on the river bottom appears to be the major factor limiting the development of bottom organisms.

As in previous years, the effects of agricultural activities and hydrological conditions were evident, and were generally similar to conditions observed in other eastern Iowa rivers. In contrast to 1986 when mean flows in the Cedar River were well above normal, 1987 river flow was the lowest present since 1977. In spite of the major hydrological differences, levels of some parameters which are frequently related to runoff and river flow, such as turbidity, suspended solids, and phosphate, exhibited little variation over the two year period. Average turbidity values of 33 and 32 NTU and total phosphate concentrations of 0.26 and 0.24 mg/L were observed upstream of the station (Station 1) in 1986 and 1987, respectively (Table 28). Average suspended solids levels were actually higher during 1987 (72 mg/L) than in 1986 (63 mg/L).

One unexpected effect of the extended dry period present during 1987 was the unusually low levels of several parameters observed during the summer. In the past, low total alkalinity, hardness, and dissolved solids values usually occurred during periods of snowmelt and runoff, or following extended periods of rainfall. However, in 1987 lowest levels of these substances were observed from mid June through mid August, during an extended dry period. These low values were probably related to the rapid downward movement of surface water through the dry unconsolidated surficial deposits into the shallow aquifers feeding the Cedar River. This rapid movement of water shortens its residence time in the surface deposits and shallow aquifer, and reduces the time available for the solubilization of calciferous materials.

The low river flows present in 1987 appeared to be more suitable for the development of algal populations than was the case during 1986. This was especially evident during the summer and early fall when high dissolved oxygen, pH, and BOD values were frequently present. Increases in these parameters are indicative of algal blooms.

In spite of unusually low flow, increased turbidity, suspended solids, phosphate, iron, and coliform levels continued to be observed at the beginning of periods of rainfall and subsequent runoff. This was especially evident late August and mid September. This pattern has been consistent throughout the study and is indicative of the significance of "nonpoint source" input from agricultural land runoff to the water quality of the Cedar River, as well as other Midwestern rivers[19]. When maximum values for parameters such as turbidity, phosphate, and ammonia are compared for high flow and low flow years it can be seen that highest levels are usually present during those years when maximum runoff occurs. This is especially apparent in the total amounts of these substances present as determined by the relative loading values (average annual concentration x cumulative runoff) shown in Table 29.

Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1987

Date	Mean Monthly Discharge (cfs)	Percent of 1951-1980 Median Discharge
January	2,099	201
February	2,730	224
March	4,190	79
April	5,109	87
May	3,151	74
June	2,139	50
July	1,908	58
August	2,804	139
September	2,191	123
October	1,418	95
November	1,473	79
December	2,295	183

*Data obtained from U.S. Geological Survey records

Table 2

Temperature (^{o}C) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 08	1.0	1.0	2.0	1.0	1.0
Jan 22	0.5	1.0	4.0	1.5	1.0
Feb 05	1.0	1.0	9.0	2.0	1.5
Feb 19	2.0	2.0	8.5	2.5	2.5
Mar 05	6.5	6.5	18.0	7.5	8.5
Mar 19	5.0	5.5	11.0	5.5	6.0
Apr 02	5.0	5.5	9.0	6.0	6.0
Apr 22	14.5	14.5	14.0	14.5	14.5
May 14	21.5	22.0	22.0	22.0	22.5
May 28	22.0	21.5	22.0	21.5	22.0
Jun 03	23.0	23.0	24.0	23.5	24.0
Jun 17	26.5	27.0	24.5	26.5	28.5
Jul 08	27.0	27.0	25.5	27.0	28.0
Jul 22	29.5	29.0	29.0	29.0	29.0
Aug 12	25.0	26.0	30.0	26.5	26.5
Aug 27	17.0	17.0	24.5	18.0	18.0
Sep 03	19.5	20.0	21.0	21.5	21.0
Sep 16	19.0	20.0	27.5	22.5	21.0
Oct 07	10.0	11.0	11.0	11.0	11.0
Oct 21	6.5	7.0	5.5	6.5	7.5
Nov 11	8.0	8.0	21.0	10.0	9.0
Nov 24	3.5	3.5	19.5	7.0	4.0
Dec 09	4.5	4.5	22.0	8.5	5.5
Dec 21	0.0	0.0	18.0	1.5	1.0

Table 3

Summary of Water Temperature Differentials and Station Output During Periods of Cedar River Sampling During 1987

Date	ΔT (^oC) U/S River (Sta. 2) vs. Discharge Canal (Sta. 5)	ΔT (^oC) U/S River (Station 2) vs. D/S River (Sta. 3)	ΔT (^oC) U/S River (Sta. 2) vs. D/S River (Sta. 4)	Station Output (% full power)
Jan 08	1.0	0.0	0.0	101
Jan 22	3.0	0.5	0.0	102
Feb 05	8.0	1.0	0.5	80
Feb 19	6.5	0.5	0.5	77
Mar 05	11.5	1.0	2.0	72
Mar 19	5.5	0.0	0.5	0
Apr 02	3.5	0.5	0.5	0
Apr 22	-0.5	0.0	0.0	0
May 14	0.0	0.0	0.5	0
May 28	0.5	0.0	0.5	0
Jun 03	1.0	0.5	1.0	0
Jun 17	-2.5	-0.5	1.5	0
Jul 08	-1.5	0.0	1.0	0
Jul 22	0.0	0.0	0.0	96
Aug 12	4.0	0.5	0.5	98
Aug 27	7.5	1.0	1.0	100
Sep 03	1.0	1.5	1.0	100
Sep 16	7.5	2.5	1.0	99
Oct 07	0.0	0.0	0.0	93
Oct 21	-1.5	-0.5	0.5	0
Nov 11	13.0	2.0	1.0	70
Nov 24	16.0	3.5	0.5	101
Dec 09	17.5	4.0	1.0	101
Dec 21	18.0	1.5	1.0	102

Table 4

Turbidity (NTU) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 08	4	5	6	7	5
Jan 22	3	5	7	4	4
Feb 05	6	6	6	6	6
Feb 19	7	7	9	7	7
Mar 05	40	23	13	26	24
Mar 19	29	29	7	28	28
Apr 02	25	24	17	24	24
Apr 22	38	37	9	34	35
May 14	32	31	22	31	31
May 28	60	60	50	59	56
Jun 03	45	48	58	58	54
Jun 17	33	34	26	35	31
Jul 08	42	36	25	34	34
Jul 22	49	49	51	59	45
Aug 12	31	37	150	72	40
Aug 27	110	110	260	110	78
Sep 03	31	37	87	52	42
Sep 16	95	100	130	110	93
Oct 07	26	27	26	27	27
Oct 21	10	9	31	18	11
Nov 11	6	8	32	10	8
Nov 24	8	9	37	20	13
Dec 09	16	15	50	21	17
Dec 21	7	6	23	9	8

Table 5

Total Solids (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	380	380	560	410	420
Jan 22	410	410	790	430	400
Feb 05	350	340	740	360	330
Feb 19	380	360	1400	400	390
Mar 05	400	370	750	400	390
Mar 19	410	400	410	410	410
Apr 02	400	400	380	410	400
Apr 22	410	400	360	410	400
May 14	370	390	310	380	370
May 28	460	450	400	460	450
Jun 03	440	460	490	480	430
Jun 17	360	350	290	320	300
Jul 08	300	280	260	270	280
Jul 22	320	330	330	370	300
Aug 12	290	310	1770	740	420
Aug 27	500	490	1420	530	370
Sep 03	350	360	1430	660	410
Sep 16	480	460	1048	680	450
Oct 07	340	330	340	340	340
Oct 21	360	360	420	390	370
Nov 11	370	370	1100	540	410
Nov 24	380	370	1528	770	510
Dec 09	410	400	2030	810	460
Dec 21	317	350	1200	420	370

Table 6

Dissolved Solids (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	350	315	530	390	390
Jan 22	400	390	750	320	380
Feb 05	320	320	720	360	330
Feb 19	360	350	1330	380	350
Mar 05	320	320	690	340	330
Mar 19	320	340	390	330	330
Apr 02	340	350	310	340	350
Apr 22	300	300	320	310	300
May 14	230	240	220	250	250
May 28	280	300	280	280	290
Jun 03	280	270	280	270	250
Jun 17	190	170	190	180	190
Jul 08	170	170	170	180	160
Jul 22	170	170	180	170	160
Aug 12	180	180	1410	510	290
Aug 27	220	210	980	260	230
Sep 03	240	350	1190	530	300
Sep 16	240	240	810	440	270
Oct 07	250	250	270	260	250
Oct 21	330	320	310	320	310
Nov 11	340	340	1022	480	370
Nov 24	330	320	1374	660	460
Dec 09	350	360	1850	730	400
Dec 21	350	310	1150	390	330

Table 7

Suspended Solids (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	8	18	7	10	9
Jan 22	4	4	9	4	5
Feb 05	8	9	5	8	8
Feb 19	10	10	11	12	10
Mar 05	80	44	24	64	52
Mar 19	58	64	11	61	63
Apr 02	44	47	29	47	48
Apr 22	86	92	16	82	88
May 14	83	86	60	85	80
May 28	140	130	100	130	130
Jun 03	140	150	160	170	140
Jun 17	89	100	60	90	70
Jul 08	100	97	53	85	80
Jul 22	140	130	130	160	140
Aug 12	97	97	320	170	110
Aug 27	210	220	430	230	230
Sep 03	75	80	170	110	94
Sep 16	200	190	220	220	180
Oct 07	65	77	68	74	68
Oct 21	14	15	78	40	19
Nov 11	22	19	66	23	16
Nov 24	15	16	61	18	27
Dec 09	29	27	85	32	31
Dec 21	6	6	34	13	12

Table 8

Dissolved Oxygen (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations				
	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	13.4	13.4	12.6	13.4	13.4
Jan 22	14.4	14.0	12.3	13.8	13.4
Feb 05	14.3	15.4	13.8	13.8	12.9
Feb 19	13.0	12.8	1.5	12.5	12.3
Mar 05	11.8	12.0	8.6	11.9	11.3
Mar 19	12.1	12.2	16.6	12.2	12.6
Apr 02	12.6	12.6	12.0	12.4	13.0
Apr 22	9.4	10.2	10.1	10.0	10.6
May 14	11.8	12.4	10.5	13.2	13.7
May 28	9.2	9.4	8.8	9.0	9.0
Jun 03	10.5	11.0	9.0	10.4	11.7
Jun 17	10.5	11.4	9.2	11.0	12.6
Jul 08	12.5	13.2	8.6	11.7	14.5
Jul 22	15.7	12.8	8.8	11.0	13.8
Aug 12	11.0	12.1	6.4	10.6	12.8
Aug 27	8.7	8.8	8.0	8.9	9.0
Sep 03	14.2	14.9	8.0	14.8	16.8
Sep 16	8.0	8.2	7.0	7.6	7.7
Oct 07	13.2	12.7	12.0	13.2	12.8
Oct 21	14.4	14.0	13.0	13.9	12.2
Nov 11	14.0	15.2	10.3	13.8	14.5
Nov 24	13.3	13.6	10.1	12.5	12.8
Dec 09	11.9	12.2	9.2	12.2	12.4
Dec 21	13.0	13.8	10.8	14.1	13.8

Table 9

Carbon Dioxide (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations				
	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	10	11	9	8	11
Jan 22	5	9	6	14	14
Feb 05	4	3	6	3	4
Feb 19	4	4	2	4	5
Mar 05	4	5	1	2	3
Mar 19	3	3	2	3	4
Apr 02	3	3	4	5	3
Apr 22	4	3	4	3	3
May 14	2	2	3	1	2
May 28	4	4	4	4	4
Jun 03	<1	<1	<1	<1	<1
Jun 17	1	1	1	1	1
Jul 08	1	1	7	1	<1
Jul 22	<1	<1	<1	<1	<1
Aug 12	<1	<1	*	<1	<1
Aug 27	26	20	*	6	4
Sep 03	3	4	*	2	<1
Sep 16	10	3	10	4	3
Oct 07	4	2	<1	2	2
Oct 21	11	7	6	3	6
Nov 11	6	6	10	12	17
Nov 24	5	4	<5	3	3
Dec 09	5	5	*	3	3
Dec 21	21	26	*	9	6

*Unable to calculate

Table 10

Total Alkalinity ($mg/L-CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	224	228	210	220	214
Jan 22	238	242	128	226	236
Feb 05	206	206	154	202	208
Feb 19	206	216	238	210	210
Mar 05	188	186	142	186	188
Mar 19	205	204	202	201	204
Apr 02	208	204	208	202	202
Apr 22	196	198	220	196	196
May 14	134	122	142	124	120
May 28	176	176	168	172	166
Jun 03	159	158	160	160	156
Jun 17	122	118	120	118	120
Jul 08	110	100	124	108	110
Jul 22	100	98	100	98	98
Aug 12	100	100	104	102	92
Aug 27	160	146	82	148	142
Sep 03	168	160	94	134	160
Sep 16	160	158	120	136	146
Oct 07	164	156	164	154	156
Oct 21	216	216	220	220	220
Nov 11	212	212	100	190	210
Nov 24	214	206	192	200	206
Dec 09	234	238	105	202	228
Dec 21	226	220	64	206	220

Table 11

Carbonate Alkalinity (mg/L-CaCO) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	<1	<1	<1	<1	<1
Jan 22	<1	<1	<1	<1	<1
Feb 05	<1	<1	<1	<1	<1
Feb 19	<1	<1	<1	<1	<1
Mar 05	<1	<1	<1	<1	<1
Mar 19	<1	<1	<1	<1	<1
Apr 02	<1	<1	<1	<1	<1
Apr 22	<1	<1	<1	<1	<1
May 14	<1	<1	<1	<1	<1
May 28	<1	<1	<1	<1	<1
Jun 03	5	6	2	<1	<1
Jun 17	<1	<1	<1	8	8
Jul 08	<1	<1	<1	<1	<1
Jul 22	36	18	18	<1	24
Aug 12	20	32	<1	20	32
Aug 27	<1	<1	<1	30	36
Sep 03	<1	<1	<1	<1	<1
Sep 16	<1	<1	<1	<1	20
Oct 07	<1	<1	12	<1	<1
Oct 21	<1	<1	<1	<1	<1
Nov 11	<1	<1	<1	<1	<1
Nov 24	<1	<1	<1	<1	<1
Dec 09	<1	<1	<1	<1	<1
Dec 21	<1	<1	<1	<1	<1

Table 12

Unit of pH from the Cedar River
Near the Duane Arnold Energy Center During 1987

	Sampling Locations				
Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	7.8	7.8	7.8	7.9	7.8
Jan 22	8.2	7.9	7.8	7.7	7.7
Feb 05	8.2	8.3	7.8	8.3	8.2
Feb 19	8.2	8.2	8.3	8.2	8.0
Mar 05	8.1	8.0	8.3	8.3	8.2
Mar 19	8.2	8.2	8.3	8.2	8.1
Apr 02	8.2	8.2	8.1	8.1	8.2
Apr 22	8.1	8.2	8.1	8.1	8.2
May 14	8.1	8.1	8.0	8.3	8.1
May 28	7.9	7.9	7.9	7.9	7.9
Jun 03	8.5	8.5	8.6	8.7	8.8
Jun 17	8.3	8.3	8.3	8.3	8.4
Jul 08	8.3	8.3	7.5	8.3	8.8
Jul 22	9.2	9.1	9.1	9.1	9.3
Aug 12	9.1	9.1	7.4	9.0	9.1
Aug 27	7.1	7.2	7.4	7.6	7.9
Sep 03	8.0	7.9	7.5	8.1	8.6
Sep 16	7.5	8.0	7.3	7.7	7.9
Oct 07	8.0	8.2	8.4	8.3	8.3
Oct 21	7.7	7.9	8.0	8.3	8.0
Nov 11	8.0	7.9	7.4	7.6	7.5
Nov 24	8.1	8.2	8.0	8.1	8.2
Dec 09	8.1	8.2	7.9	8.1	8.3
Dec 21	7.5	7.4	8.0	7.8	8.0

Table 13

Total Hardness (mg/L-$CaCO_3$) from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	346	338	428	360	352
Jan 22	336	322	536	344	330
Feb 05	342	312	538	320	298
Feb 19	294	306	574	361	300
Mar 05	268	279	488	284	276
Mar 19	315	301	318	286	286
Apr 02	*	365	380	310	330
Apr 22	312	278	322	288	288
May 14	212	276	271	254	238
May 28	288	256	308	272	258
Jun 03	220	218	222	222	206
Jun 17	176	171	162	170	182
Jul 08	146	142	161	155	148
Jul 22	155	139	143	142	138
Aug 12	224	186	856	356	214
Aug 27	224	194	696	232	260
Sep 03	240	232	835	408	314
Sep 16	272	238	582	350	264
Oct 07	240	270	220	200	260
Oct 21	285	285	280	275	280
Nov 11	340	330	720	406	330
Nov 24	270	280	930	470	350
Dec 09	338	324	1270	602	384
Dec 21	342	376	826	412	332

*Analytical error

Table 14

Calcium Hardness (mg/L-$CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	204	202	272	221	215
Jan 22	216	212	358	226	222
Feb 05	194	190	348	200	196
Feb 19	198	197	380	212	202
Mar 05	180	205	322	188	185
Mar 19	204	190	229	192	202
Apr 02	230	230	220	215	225
Apr 22	178	176	200	178	180
May 14	120	110	120	110	100
May 28	166	152	162	164	161
Jun 03	115	118	125	112	110
Jun 17	82	80	86	84	83
Jul 08	58	58	75	34	34
Jul 22	55	49	51	59	45
Aug 12	86	98	438	164	100
Aug 27	146	122	412	140	140
Sep 03	150	130	498	244	148
Sep 16	126	144	330	218	148
Oct 07	130	120	120	130	120
Oct 21	170	170	170	180	180
Nov 11	194	208	451	246	204
Nov 24	180	160	600	320	220
Dec 09	211	198	847	364	224
Dec 21	162	200	530	232	224

Table 15

Total Phosphorus (mg/L-P) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	0.15	0.16	0.20	0.17	0.18
Jan 22	0.16	0.15	0.58	0.16	0.17
Feb 05	0.32	0.29	0.86	0.33	0.31
Feb 19	0.20	0.20	1.5	0.26	0.24
Mar 05	0.31	0.28	1.2	0.34	0.34
Mar 19	0.23	0.22	0.19	0.21	0.21
Apr 02	0.06	0.05	0.01	0.04	0.06
Apr 22	0.27	0.25	0.32	0.23	0.26
May 14	0.07	0.23	0.25	0.20	0.19
May 28	0.33	0.30	0.26	0.31	0.29
Jun 03	0.18	0.12	0.28	0.10	0.27
Jun 17	0.21	0.31	0.22	0.31	0.27
Jul 08	0.14	0.16	0.16	0.13	0.14
Jul 22	0.26	0.23	0.32	0.16	0.24
Aug 12	0.19	0.19	1.7	0.57	0.32
Aug 27	0.48	0.48	2.3	0.59	0.38
Sep 03	0.20	0.19	1.5	0.52	0.31
Sep 16	0.49	0.45	1.4	0.64	0.56
Oct 07	0.2	0.2	0.2	0.2	0.2
Oct 21	0.2	0.2	0.5	0.2	0.2
Nov 11	0.2	0.2	1.5	0.4	0.2
Nov 24	0.3	0.3	1.2	0.6	0.3
Dec 09	0.3	0.3	1.1	0.5	0.3
Dec 21	0.2	0.2	1.6	0.4	0.3

Table 16

Soluble Orthophosphate (mg/L-P) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	0.14	0.14	0.17	0.15	0.16
Jan 22	0.13	0.13	0.30	0.14	0.14
Feb 05	0.16	0.16	0.37	0.18	0.17
Feb 19	0.14	0.14	0.45	0.15	0.15
Mar 05	0.14	0.14	0.36	0.16	0.15
Mar 19	0.06	0.06	0.06	0.06	0.07
Apr 02	0.04	0.04	0.01	0.03	0.03
Apr 22	0.05	0.04	0.21	0.04	0.04
May 14	0.02	<0.01	<0.01	0.01	0.01
May 28	0.12	0.11	0.11	0.10	0.11
Jun 03	0.05	0.04	0.07	0.04	0.03
Jun 17	0.02	0.02	0.07	0.01	0.01
Jul 08	0.03	0.03	0.04	0.04	0.03
Jul 22	0.03	0.01	0.01	0.01	0.01
Aug 12	0.09	0.02	0.52	0.14	0.07
Aug 27	0.37	0.36	1.3	0.40	0.28
Sep 03	0.03	0.11	0.69	0.29	0.15
Sep 16	0.17	0.10	0.66	0.24	0.15
Oct 07	<0.1	<0.1	<0.1	<0.1	<0.1
Oct 21	<0.1	<0.1	<0.1	<0.1	<0.1
Nov 11	<0.1	<0.1	0.5	0.2	0.1
Nov 24	0.3	0.3	0.6	0.4	0.3
Dec 09	0.2	0.2	0.6	0.3	0.2
Dec 21	0.1	<0.1	0.8	0.1	0.1

Table 17

Ammonia (mg/L-N) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	0.04	0.02	0.17	0.03	0.03
Jan 22	0.05	0.05	0.07	0.05	0.05
Feb 05	0.15	0.16	0.08	0.14	0.14
Feb 19	0.10	0.09	0.09	0.10	0.10
Mar 05	0.11	0.13	0.04	0.09	0.11
Mar 19	0.03	0.04	0.35	0.03	0.03
Apr 02	0.05	0.05	0.10	0.03	0.04
Apr 22	0.07	0.09	0.09	0.08	0.08
May 14	0.10	0.10	0.16	0.07	0.05
May 28	0.02	0.03	0.05	0.05	0.04
Jun 03	<0.01	<0.01	<0.01	<0.01	<0.01
Jun 17	<0.01	<0.01	<0.01	<0.01	<0.01
Jul 08	0.01	0.03	0.03	0.01	<0.01
Jul 22	0.02	0.04	0.03	0.08	0.03
Aug 12	0.04	0.02	0.21	0.06	0.01
Aug 27	0.07	0.07	0.25	0.07	0.12
Sep 03	0.02	0.02	0.07	0.04	0.01
Sep 16	0.01	<0.01	0.08	0.03	0.01
Oct 07	<0.1	<0.1	<0.1	<0.1	<0.1
Oct 21	<0.1	<0.1	<0.1	<0.1	<0.1
Nov 11	<0.1	<0.1	<0.1	<0.1	<0.1
Nov 24	<0.1	<0.1	<0.1	<0.1	<0.1
Dec 09	<0.1	<0.1	<0.1	<0.1	<0.1
Dec 21	<0.1	<0.1	<0.1	<0.1	<0.1

Table 18

Nitrate (mg/L-N) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	6.7	6.6	7.4	7.1	7.1
Jan 22	7.1	7.0	8.0	7.2	7.3
Feb 05	5.9	6.0	6.9	6.2	6.2
Feb 19	6.3	6.2	9.5	6.5	6.4
Mar 05	7.0	6.8	6.9	7.1	7.3
Mar 19	8.3	8.2	4.7	8.2	8.2
Apr 02	8.7	8.6	6.8	8.5	8.5
Apr 22	8.2	8.2	3.3	8.1	8.2
May 14	4.6	4.5	3.6	4.4	4.4
May 28	13.0	6.1	6.0	6.2	6.2
Jun 03	6.2	6.1	6.0	6.1	6.0
Jun 17	2.6	2.5	2.2	2.3	2.4
Jul 08	1.1	1.0	1.0	1.0	1.0
Jul 22	2.5	2.5	2.6	2.6	2.5
Aug 12	1.2	1.0	4.6	2.1	1.4
Aug 27	5.0	4.6	9.7	5.3	4.9
Sep 03	5.4	5.3	16.0	8.9	5.8
Sep 16	4.1	4.0	8.4	5.3	4.2
Oct 07	3.8	3.6	3.7	3.8	3.6
Oct 21	4.1	4.2	3.7	4.0	4.2
Nov 11	3.6	3.5	7.6	5.6	3.8
Nov 24	4.6	4.5	14.0	7.7	5.7
Dec 09	6.8	6.8	24.0	11.0	7.5
Dec 21	7.6	7.3	16.0	8.0	7.5

Table 19

Total Iron (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1987

	Sampling Locations				
Date 1987	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	0.13	0.17	0.23	0.19	0.18
Jan 22	0.15	0.06	0.17	0.06	0.07
Feb 05	0.25	0.16	0.28	0.16	0.17
Feb 19	0.34	0.12	0.39	0.14	0.21
Mar 05	0.86	0.52	0.43	0.32	0.46
Mar 19	1.7	1.6	0.58	1.6	1.3
Apr 02	0.87	0.51	0.42	0.45	0.49
Apr 22	0.78	0.88	0.27	0.77	0.76
May 14	0.26	0.24	0.39	0.29	0.26
May 28	0.72	0.53	0.58	0.54	0.69
Jun 03	0.46	0.44	0.84	0.51	0.34
Jun 17	0.45	0.32	0.28	0.32	0.21
Jul 08	0.26	0.35	0.33	0.40	0.42
Jul 22	1.0	0.79	1.2	0.66	0.86
Aug 12	0.20	0.17	2.1	0.88	0.36
Aug 27	1.2	1.4	3.4	1.4	1.0
Sep 03	0.43	0.30	1.6	0.78	0.59
Sep 16	1.2	1.1	1.6	1.0	1.0
Oct 07	0.24	0.21	0.32	0.29	0.20
Oct 21	0.12	0.11	0.37	0.23	0.14
Nov 11	0.12	0.10	0.77	0.21	0.16
Nov 24	0.18	0.17	0.81	0.41	0.27
Dec 09	0.36	0.48	1.6	0.70	0.36
Dec 21	0.14	0.19	0.76	0.19	0.17

Table 20

Biochemical Oxygen Demand (5-Day in mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	<1	<1	<1	1	<1
Jan 22	2	4	2	3	3
Feb 05	2	2	2	2	2
Feb 19	<1	<1	11	2	2
Mar 05	3	3	2	2	3
Mar 19	2	2	2	2	2
Apr 02	2	2	2	1	2
Apr 22	4	4	3	4	4
May 14	10	11	7	9	11
May 28	8	10	8	8	8
Jun 03	10	11	10	11	11
Jun 17	*	*	*	*	*
Jul 08	16	13	7	12	14
Jul 22	14	16	14	14	15
Aug 12	12	13	35	20	15
Aug 27	5	5	10	5	14
Sep 03	8	9	16	10	10
Sep 16	6	7	12	10	7
Oct 07	10	11	12	12	12
Oct 21	4	4	3	4	4
Nov 11	4	4	6	4	4
Nov 24	6	6	11	7	5
Dec 09	2	1	3	2	1
Dec 21	<1	<1	2	<1	<1

*Laboratory accident

Table 21

Coliform Bacteria (Total Org/100 ml) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations				
	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	3500	2600	1200	1700	1900
Jan 22	170	60	30	130	30
Feb 05	1100	310	140	270	240
Feb 19	260	200	400	70	110
Mar 05	1500	1300	40	1300	1100
Mar 19	2600	2800	1700	2300	2900
Apr 02	1400	2100	900	1900	700
Apr 22	900	1500	1000	1100	600
May 14	600	200	20	2000	100
May 28	1100	1600	300	1300	1800
Jun 03	100	100	500	400	300
Jun 17	*	200	*	*	*
Jul 08	300	100	1000	200	1000
Jul 22	*	3000	300	300	700
Aug 12	600	400	6000	800	700
Aug 27	31,000	33,000	26,000	36,000	28,000
Sep 03	200	200	1900	700	300
Sep 16	43,000	45,000	43,000	44,000	75,000
Oct 07	600	1200	600	600	700
Oct 21	170	140	150	180	140
Nov 11	210	210	900	600	260
Nov 24	2400	900	800	1100	1200
Dec 09	3000	2500	700	2800	2700
Dec 21	290	630	900	250	220

*Laboratory accident

Table 22

Coliform Bacteria (Fecal Org/100 ml) Values from the Cedar River Near the Duane Arnold Energy Center During 1987

Date 1987	Sampling Locations				
	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 08	130	120	20	160	130
Jan 22	<10	<10	<10	<10	10
Feb 05	80	50	20	40	30
Feb 19	<10	<10	<10	<10	<10
Mar 05	120	100	10	80	50
Mar 19	330	380	130	360	270
Apr 02	150	130	130	110	60
Apr 22	100	160	230	60	80
May 14	20	300	20	10	<10
May 28	500	700	300	800	700
Jun 03	30	60	90	60	40
Jun 17	60	60	10	20	310
Jul 08	160	200	150	170	190
Jul 22	30	30	50	80	40
Aug 12	400	100	*	*	*
Aug 27	15,000	10,000	24,000	18,000	9,600
Sep 03	90	120	200	100	90
Sep 16	14,000	23,000	15,000	12,000	23,000
Oct 07	60	120	70	50	130
Oct 21	40	30	30	10	50
Nov 11	30	70	50	40	30
Nov 24	90	100	50	100	80
Dec 09	450	240	170	350	330
Dec 21	100	50	150	80	20

*Unable to quantify

Table 23

Quarterly Chemical Analysis - 1987

Station	Cl^- (mg/L)	SO_4 (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
			March 19					
1. Lewis Access	24	33	<10	<50	<10	50	<1	70
2. Upstream DAEC	22	33	<10	<50	<10	50	<1	<20
3. Downstream DAEC	23	23	<10	<50	<10	50	<1	40
4. 1/2 Mile Below Plant	22	32	<10	<50	<10	50	<1	40
5. Discharge Canal	23	70	<10	<50	<10	110	<1	60
			July 22					
1. Lewis Access	-	-	<20	<10	<10	110	<1	<20
2. Upstream DAEC	-	-	<20	<10	<10	80	<1	<20
3. Downstream DAEC	-	-	<20	<10	<10	70	<1	<20
4. 1/2 Mile Below Plant	-	-	<20	<10	<10	80	<1	<20
5. Discharge Canal	-	-	-	<10	<10	100	<1	<20

Table 24

Benthic Macroinvertebrates
Collected from Ponar Grab Samples at Sites 50 and 51

27 April and 8 October 1987

	PONAR DREDGE GRAB SAMPLES			
	27 April 1987		8 October 1987	
Taxon	Site 50	Site 51	Site 50	Site 51
Ephemeroptera *Hexagenia limbata*	1	-	-	-
Coleoptera Elmidae larva	1	-	1	-
Total No. of Organisms	2	0	1	0
Total No. of Species	2	0	1	0

Note: Tabled numbers represent the total No. of organisms found in a composite of two petite ponar grab samples from each site.

Table 25

Benthic Macroinvertebrates
Collected from the Cedar River and Discharge Canal
near the Duane Arnold Energy Center

12 June to 24 July 1987

Artificial Substrate Collections

	Site 49			Site 50			Site 51			Site 61			Discharge Canal	
Taxon	A	B	C	A	B	C	A	B	C	A	B	C	A	B
Trichoptera														
Hydropsyche sp.	4	230	104	13	29	4	57	99	2	48	55		8	[illegible]
Hydropsyche bidens	6	75	133	389	426	145	229	100	134	99	179		-	[illegible]
Hydropsyche orris	17	194	589	258	356	106	308	179	170	206	235		3	[illegible]
Hydropsyche simulans	-	-	3	7	31	-	18	5	10	9	8		-	[illegible]
Cheumatopsyche sp.	-	1	2	-	-	4	1	1	1	-	9		-	[illegible]
Cerclea sp.	-	1	-	-	-	-	-	-	-	-	-		-	[illegible]
Diptera														
Chironomidae (larvae/pupae)	364	1284	202	15	137	-	239	337	141	452	638		807	[illegible]
Hemerodromia rogatoris	3	-	-	-	1	1	1	2	-	1	11		-	
Atherix sp.	-	11	28	-	8	-	1	12	9	13	41		2	
Simulium sp.	-	-	-	-	-	-	-	-	-	-	-		2	
Ephemeroptera														
Baetis sp.	-	-	-	2	-	-	-	-	-	-	-		-	
Caenis sp.	-	5	47	1	-	-	8	9	2	48	47		-	
Tricorythodes sp.	-	-	6	-	-	-	3	-	1	9	9		-	
Isonychia sp.	-	-	1	-	-	-	3	-	-	4	3		-	
Heptageniidae	-	-	-	-	-	-	-	-	-	-	3		-	
Heptagenia sp.	-	-	2	-	-	-	-	-	-	-	-		-	
Heptagenia flavescens	-	-	-	-	-	-	-	-	-	5	-		-	
Stenonema sp.	-	-	1	2	-	-	1	-	-	3	-		-	
Coleoptera														
Stenelmis sp.	-	-	4	4	1	3	4	1	-	-	3		-	
Plecoptera														
Pteronarcys sp.	-	-	-	-	-	-	-	-	1	-	-		-	
Megaloptera														
Corydalus cornutus	-	-	1	-	-	-	-	-	2	-	-		-	
Gastropoda														
Physa sp.	-	-	-	-	-	-	-	-	-	-	1		26	
Hydracarina														
Hydrachna sp.	-	1	-	-	-	-	-	-	-	-	-		-	
Pelecypoda														
Musculium sp.	-	-	-	-	-	-	-	-	-	-	-		2	
Hirudinea	-	-	-	-	-	-	-	-	-	-	-		20	
Total No. of Organisms	394	1800	1123	691	989	263	873	745	473	897	1242		870	
Total No. of Species	5	9	14	9	8	6	13	10	11	12	14		8	

Note: To convert No. of organisms counted to No./m^2 multiply by 6.25

Table 25 (cont.)

Benthic Macroinvertebrates
Collected from the Cedar River and Discharge Canal
near the Duane Arnold Energy Center

8 October to 4 December 1987

	Artificial Substrate Collections												Discharge Canal	
	Site 49			Site 50			Site 51			Site 61				
xon	A	B	C	A	B	C	A	B	C	A	B	C	A	B
ichoptera														
Hydropsyche sp.	23	79	65	231	58	81	41	24	129	67	52	140	5	-
Hydropsyche bidens	9	49	23	56	7	2	7	0	12	8	1	4	-	1
Hydropsyche orris	10	20	17	41	2	9	5	2	9	3	-	12	-	1
Cheumatopsyche sp.	1	-	2	-	1	-	-	-	1	1	1	-	-	-
iptera														
Chironomidae	172	250	258	404	128	107	96	50	192	140	189	332	7	23
Atherix sp.	2	6	2	-	2	2	1	2	2	2	1	4	2	1
Simulium sp.	-	-	1	-	-	-	3	-	2	-	-	-	-	-
phemeroptera														
Caenis sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Tricorythodes sp.	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Isonychia sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Heptageniidae	-	3	2	-	-	-	-	1	2	7	1	-	-	-
Heptagenia flavescens	3	5	8	1	-	5	2	1	7	8	2	8	1	-
Stenonema femoratum	5	22	8	5	7	11	2	-	6	18	3	4	-	-
Coleoptera														
Stenelmis sp.	-	4	-	-	-	-	-	-	-	-	-	-	-	1
Plecoptera														
Pteronarcys sp.	86	136	292	231	63	75	48	31	252	56	98	248	10	1
Odonata														
Argia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Megaloptera														
Corydalus cornutus	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Hemiptera														
Corixidae	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Amphipoda														
Hyalella azteca	-	-	-	-	-	-	-	-	-	-	-	-	1	2
Gastropoda														
Physa sp.	-	1	-	-	-	-	2	5	8	-	-	-	30	31
Hirudinea	-	-	-	-	-	-	-	-	-	-	-	-	4	23
Total No. of Organisms	311	576	679	969	268	292	207	117	622	311	348	752	61	85
Total No. of Species	9	12	12	7	8	8	10	10	12	11	9	8	9	9

Note: To convert No. of organisms counted to No./m2 multiply by 6.25

Table 26

Daily Numbers of Fish Impinged at the
Duane Arnold Energy Center
January - December 1987

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	11	0	3	1	0	0	0	0	0	0	0	0
2	26	1	4	1	0	0	0	0	0	0	0	0
3	11	1	5	0	0	0	0	0	0	0	0	0
4	4	3	8	0	0	0	0	0	0	0	0	0
5	1	0	1	0	0	0	0	0	0	0	0	0
6	14	4	2	0	0	0	0	0	0	0	0	2
7	5	1	7	0	0	0	0	0	0	0	0	0
8	8	0	1	0	0	0	0	0	0	0	0	0
9	4	0	1	0	0	0	0	0	0	0	0	0
10	0	10	3	0	0	0	0	0	0	0	0	2
11	0	4	1	0	0	0	0	1	0	0	0	0
12	0	1	1	0	0	0	0	1	0	0	0	0
13	4	5	1	0	0	0	0	0	0	0	0	0
14	1	3	5	0	0	0	0	0	0	0	0	0
15	0	1	1	0	0	0	0	0	0	0	0	0
16	3	3	0	0	0	0	0	0	0	0	0	0
17	0	3	0	0	0	0	0	0	0	0	1	0
18	0	6	0	0	0	0	0	0	0	0	0	0
19	0	5	0	0	0	0	0	0	0	0	0	0
20	0	4	1	0	0	0	0	0	0	0	0	0
21	0	3	1	0	0	0	0	0	0	0	1	1
22	0	2	0	0	0	0	0	0	0	0	0	0
23	0	5	1	0	0	0	0	2	0	0	0	0
24	0	5	6	0	0	0	0	0	0	0	0	1
25	0	5	0	0	0	0	0	0	0	0	1	0
26	0	2	2	0	0	0	0	0	0	1	0	0
27	0	8	1	0	0	0	0	0	0	0	0	0
28	1	2	1	0	0	0	0	0	0	0	0	0
29	1		0	0	0	0	0	0	0	0	0	1
30	2		0	0	0	0	0	0	0	0	0	2
31	0		0		0		0	0		0		0
Total	96	87	57	2	0	0	0	4	0	1	3	11

Annual Tot. 261

Table 27

Comparison of Average Values for Several Parameters at Upstream, Downstream, and Discharge Canal Locations at the Duane Arnold Energy Center During Periods of Station Operation* - 1987

Parameter	Upstream (Sta. 2)	Discharge Canal (Sta. 5)	Mixing Zone (Sta. 3)	Downstream (Sta. 4)
Temperature (^oC)	10.0	17.7	11.3	10.7
Dissolved Solids (mg/L)	295	950	427	323
Total Hardness (mg/L)	275	643	350	293
Total Phosphate (mg/L)	0.25	1.14	0.39	0.29
Nitrate (mg/L as N)	5.0	9.7	6.3	5.4
Iron (mg/L)	0.40	1.04	0.49	0.35

*Excludes the period March 19 through July 8 and October 21, 1987

Table 28

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream from the Duane Arnold Energy Center*
1972-1987

Year	Mean Flow (cfs)	Turbidity (NTU)	Total PO_4 (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7
1973	7,900	28	0.84	0.36	1.5	4.0
1974	5,580	29	2.10	0.17	4.2	4.7
1975	4,206	58	1.08	0.33	2.8	6.5
1976	2,082	41	0.25	0.25	2.8	7.3
1977	1,393	15	0.33	0.52	2.9	6.5
1978	3,709	23	0.26	0.22	4.4	3.3
1979	7,041	26	0.29	0.12	6.6	2.5
1980	4,523	40	0.34	0.19	5.4	4.3
1981	3,610	33	0.77	0.24	6.0	6.5
1982	7,252	43	0.56	0.23	8.0	5.1
1983	8,912	22	0.25	0.10	8.6	3.3
1984	7,325	40	0.32	0.10	5.9	3.9
1985	3,250	30	0.31	0.11	4.8	6.7
1986	6,475	33	0.26	0.10	6.8	3.7
1987	2,625	32	0.24	0.06	5.6	5.8

*Data from Lewis Access location (Station 1)

Table 29

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Arnold Energy Center*
1972-1987

Year	Mean Flow	Cumulative Runoff (in)	Turbidity	Relative Loading Values Total PO_4	Ammonia	Nitrate	BOD
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28

*Data from Lewis Access location (Station 1)

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